

Caterina Tiazzoldi

Applied Responsive Devices

**A methodological proposal to enhance the interaction
between analogical and digital approaches in architecture**

Caterina Tiazzoldi¹

Assistant Professor, PhD

GSAPP, Columbia University

caterina@tiazzoldi.org

DIPRADI Politecnico di Torino

tiazzoldi@nuovaordentra.org

Caterina Tiazzoldi

Applied Responsive Devices

A methodological proposal to enhance the interaction between analogical and digital approaches in architecture

Abstract

"In a complex-structured city in which the interactions among parts intensify; in which the number of decision-makers and cultural scenarios overlap, interconnect and sometimes collide; in which the temporal dimensions of the citizens are dissimilar; in which local and global, physical and virtual dimensions co-exist, it is necessary to identify a set of design tools which could respond to design complexity. That is why in the last fifteen years architects have adopted advanced digital tools such as algorithms, dynamic relationships, parametric systems, mapping, morphogenesis, cellular automata and bifurcation with broken symmetry.

In the first phase architects' interest focused on the direct transposition into the architecture of digital tools deriving from other scientific fields. The use of such tools led architects to discover forms that were inconceivable with traditional procedures. Nevertheless, in the mid-1990s the lack of control of tools that were not specific to architecture engendered a drastic reduction in the initial enthusiasm for such an approach"².

The research Applied Responsive Devices (ARD), developed by the Nonlinear Solutions Unit at Columbia University Architecture School, focuses not on the tools but on the methodologies developed in other scientific fields. ARD examines how it is possible to set up a model that operates a correct interaction between the analogical and digital environment. It analyses the possible applications of a model (to demonstrate, to analyse and to discover) and the properties that it should embed (resemblance, repeatability and robustness) to be efficient.

The methods contained in this proposal investigate the existing relationships between the perception of a specific architectural condition and its translation into a set of elements that can be manipulated through computer models. It probes how a given problem can be translated into a codified symbolic language.

In fact, some architectural problems can be managed with a code, consisting of a set of rules, each of which performs particular actions every time its conditions are satisfied by a specific informational attribute. ARD's interest is to embed sets of constraints within the modelling process that affect the decision-making of the designer. This project aims to develop an innovative tool that assists a decision-maker to take into account a number of different parameters. The goal is to enhance architecture's capacity to respond to specific environmental requirements with an adaptable physicality. From an epistemological perspective ARD's research operates as a heuristic device aiming to challenge the boundary existing between the Measurable and Non-measurable dimensions in architecture.

1. The change of paradigm: from analogical model to digital code

In science, codes are the translation into digital symbolic language of a conceptual apparatus or of an analogous model. It is legitimate to raise the question of which conceptual apparatus in architecture precedes the code.

To answer this question an NSU researcher analysed the applications and properties of the scientific model. This operation was driven by the wish identify models' architectural correspondents. The advanced research lab Nonlinear Solution Unit at the graduate school of NSU aims to understand not the techniques but the methodologies deriving from other scientific fields. The motivating factor at NSU is the will to consolidate the research field of complex systems in architecture. The goal of NSU is to promote and support research and educational projects related to complex dynamics in architecture by taking advantage of the creative and scientific potential of the projects developed within the GSAPP.

In the search for the definition of the abstract apparatus that precedes the architectural code it is possible to assume the architectural diagram as the code predecessor, as the analogous apparatus preceding the digital tool. To justify this assumption it is necessary to analyse some of the properties characterising the use of the model (as the predecessor of the code in the scientific field) and of the diagram.

If we compare the American architect Peter Eisenman's idea of the diagram and the model concept of the scientist John Holland³, the similitude between the two tools appears clearly. For Eisenman, as for Holland, diagrams and models have three types of applications: to analyse, to demonstrate and to discover. According to Eisenman and Holland, to evaluate qualitatively and quantitatively a diagram and a model, it is necessary to estimate three properties: Resemblance, Reproducibility and Robustness.

Diagrams and models are often used as a conceptual apparatus supporting architectural and scientific reasoning. When used as analytical tools diagrams and scientific models are particularly useful in the early stages of research. They can also be useful to look for an adequate model to support a work. As the scientist Cosma Shalizi⁴ affirms, in their initial stages, some researches involve a component of chance and creativity.

One begins research by applying different interpretative models on a data set, and secondly, by modulating the parameters of the adopted model. This procedure permits us to find some emergences or patterns in a set of data. The identification of those configurations permits us to find a form of order in a system that originally appeared as chaotic.

In addition, the use of the model as an analytical tool is also very important in more advanced stages of research. As regards architecture, according to Peter Eisenman, the diagram is historically understood in two ways: as explanatory and analytical and as a generative device.⁵

The ability to process a huge amount of data with a computer allows researchers to analyse quickly the implication of different theoretical scenarios in a given situation. In other word it is possible to see which interpretative model fits better in a given case study.

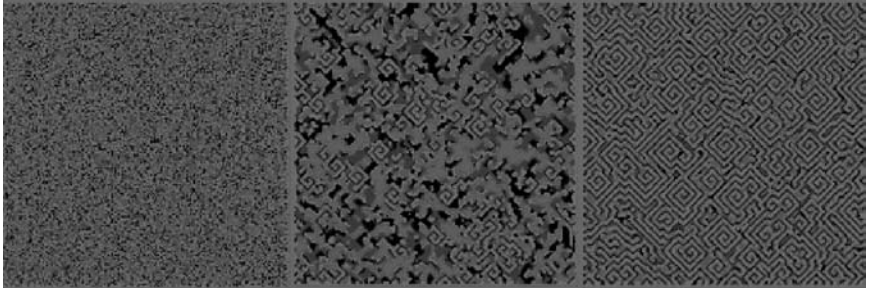


Figure 1

Different visualisations of the modulation of the parameter time on a model used to analyse some data. The modulation of one parameter on the same model allows visualisation of forms of order or patterns in a set that was initially chaotic.

In a second phase this capacity to analyse a vast amount of data quickly permits us to modulate the weight of the different parameters acting on a particular model.

‘Demonstrate’ is the second function that scientific models and architectural diagrams have in common. In effect a scientific model can be used to validate or to falsify a hypothesis.⁶

Nevertheless it is important to note that in architecture the use of a model as a demonstrative tool should be very limited. In effect the probative capacity of a model depends on its repeatability. The repeatability is the capacity to reproduce the same experiment in very similar conditions to allow comparison between the various results. In architecture the heterogeneity of the different case studies -deriving from the huge variations in the different situations- makes it almost impossible to apply an identical model to a similar case study.

‘Discover’ is the third function characterising scientific models and architectural diagrams. This is perhaps the most interesting from an architectural perspective. Given that a model is the representation of a reality through a system of rules, such rules have the capacity to produce results autonomously. They are therefore endowed with certain independence from their users. They can reveal aspects that their designer never intended. For this reason, according to John Holland, ‘A model, like a hypothesis, suggests where to look’.⁷

In the same way for Peter Eisenman the diagram is a tool allowing the designer to enter situations where it has never been before.⁸

With regard to the criteria permitting evaluation on a qualitative and qualitative level of the potentialities of a scientific model, it is possible to identify three properties: resemblance, reproducibility and robustness.

A close reading will show that the same properties can be used to evaluate the qualities of an architectural diagram.

As regards resemblance it is necessary to distinguish between two different interpretations of a model resemblance: the first, closer to the idea of formal similarity, focuses on the reproduction of a given reality on a different scale. In this first case the level of resemblance depends exclusively on a visual factor.

The second interpretation of the idea of resemblance refers to the development of a system that is capable of representing the abstract relations and the intrinsic qualities qualifying an object.

The first static interpretation is opposed by a dynamic notion of the idea of resemblance. This second understanding aims to describe the overall behaviour of a system in perpetual transformation or, as is the case in complexity sciences, in a condition far from the equilibrium.

In its second interpretation, the idea of a scientific model shows a strong similarity with the concept diagram explored by Gilles Deleuze.⁹ According to the French philosopher, a diagram is a representation or a map of the relationships and of the intense forces operating in a system. In architecture, it is possible to find a similar interpretation in Peter Eisenman's formulations. For the American architect, the diagram is a tool to mediate between a palpable object and the laws that govern its intrinsic behaviour.¹⁰

On the subject of the resemblance, models and diagrams share another similarity. According to the idea of the two mathematicians Livi and Rondoni, and the scientist John Holland, the level of resemblance of a model depends on its ability to make a system understandable by offering a simplified reading and representation of a given situation.

Regarding the relation existing between the idea of resemblance in the scientific models and diagrams Peter Eisenman affirms that the diagram 'is a representation of something in that it is not the thing itself'.¹¹

John Holland says that to select a correct model it is necessary to make some choices: to determine how to represent a problem, what kind of information the instruments we are using are capable of providing. Such a practice is necessary to get consistency between the formulation of a problem and the definition of the model adopted to resolve it.¹²

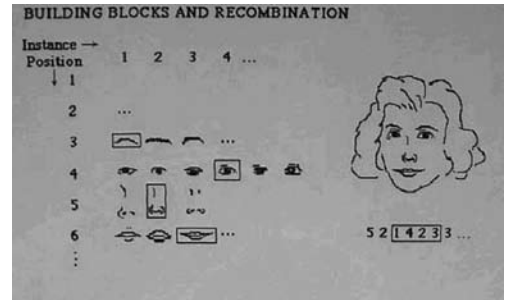
The transition from the classical science paradigm to that of the science of complexity emphasises the importance of an external subject in scientific and architectural research. According to Boltzman¹³ and Pointcare¹⁴, model-making is a subjective act. For John Holland, it is a creative reductionism.

The second property establishing similarity between scientific and architectural models (or diagrams) is reproducibility. In science, the importance of a model depends on its capacity to be reproduced in different situations. A feature of the reproducibility is the repeatability, namely the possibility to apply the same tool in similar conditions. This property transforms models in instruments of accumulation of intelligence and knowledge.

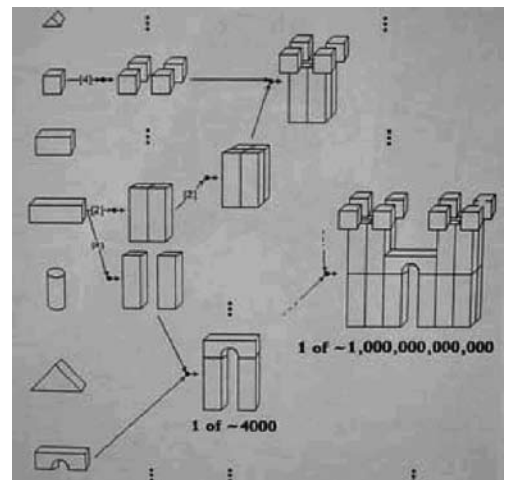
Indeed, the model becomes a heuristic device, or an interface supporting the designer's thinking.

Figure 2

Combinatorial logic operates on the elementary units of a system by recombining them in a different aggregation. In the first case the recombination of the five elementary unit or building blocks of the face of a person permits to achieve a very high number of variations. Image by courtesy of John Holland, from the lecture

**Figure 3**

Combinatorial logic operates on the elementary units of a system by recombining them in a different aggregation. In this second case the recombination of the elementary units or building blocks of a building permits a very high number of variations. Image by courtesy of John Holland,



According to the French architect Bernard Cache, models are qualified by their capacity to define some invariants¹⁵ or axioms that remain constant. The reproducibility of a model is the core of architectural problematisation of the model. To what extent is it possible to think about an instrument that is repeatable? How far is it possible to define an inner structure of a model remaining constant independently of the variations of the different case studies?

The interest of scientists and architects in the idea of codes, genetic algorithms, responsive devices and complex adaptive systems reflects the desire to obtain an instrument that is both stable in its internal organisation and capable of responding to changes in the exterior context by producing specific solutions for every problem.¹⁶ To explore the idea of the coexistence of innovation and repetition, it is possible to refer the ideas of Bateson¹⁷ (in biology), of Holland (in cognitive science) and of Deleuze (in philosophy) to the concept of combinatorial innovation. The idea of combinatorial innovation relies on achieving innovation by recombining the internal elements of a system. This combinatorial process is determined by a set of rules (more or less deterministic) established by the designer.

When we engage with the topic of the change of paradigm in architectural research, the idea of robustness reveals another strong similarity between scientific and architectural models. Robustness is the capacity of a system to resist noises and distortions. It is through the evaluation of the robustness¹⁸ of a system that a clear differentiation appears between models or diagrams and their translation into a symbolic language or a code. It is through the robustness that the change of paradigm has the strongest consequences. In effect the code is an expression in a symbolic language that operates through a set of rules. The code limits itself to accomplish exclusively the operations that have been explicitly stated.

The possible ambiguities in the message cannot be erased by use of the culture or the collective memory of its users. The code is not able to reveal any type of hidden information. Any missing or incomplete information, which normally could be integrated by human intervention, cannot be supplied by the simple application of the set of rules embedded in the code.

According to computer scientist William Wang, in the case of artificial language, it is almost impossible to process with software messages that any human being would understand immediately.

It is in its relation with robustness that a digital tool like the code differs from analogous apparatus such as a model or a diagram. The code is more rigid. The translation in a codified version of a specific language strongly affects its robustness or adaptive capacity to respond to noises and distortions.

Nevertheless, it is from its *non-robustness* or *non-adaptive capacity* that a very interesting peculiarity of scientific and architectural codes emerges. In effect, the codes can be used as creative and exploratory tool. Because they are executing the set of rules listed by its author, they are somehow self-sufficient: they are able to produce some results independently of the author or users. The application code is similar to the surrealists' use of *Automatism*.¹⁹ The code becomes a tool that is able to overcome the theoretical and formal level of its user barriers and self-censorship. Peter Eisenman says that automatism by being self-sufficient can produce something far from any prefigured idea of the designer.²⁰

The research Applied Responsive Devices aims to develop an innovative decision-maker tool enhancing architectural capacity to answer specific environmental and design requirements with its adaptable physicality. An Applied Responsive Device is a tool mediating between the potentialities of the analogous architectural model and the digital code.

ARD focuses on the qualitative and quantitative understanding of algorithmic, performative devices applied to the constructive reality of the built environment.

The NSU ARD research has the challenge of obtaining a repeatable and robust tool which can combine and mediate between mathematical performance data, the use of exploration and simulation software and empirical architectural applications.

As demonstrated in the projects *Responsive Devices 1, 2 and 3* developed by the NSU, architectural problems can be managed with a classifier system, consisting of a set of rules, each of which performs particular actions every time its conditions are satisfied by some piece of information.

The phaonmneal pweor of the hmuan mnid
 aoccdrnig to a rscheearch at Cmabrigde
 Uinervtisy, it deosn't mttær in waht oredr
 the ltteers in a wrod are, the olny iprmoatnt
 tihng is taht the frist and lsat ltteer be in the
 rghit pclae. The rset can be a taotl mse
 and you can sitll raed it wouthit a porbelm.
 Tihs is bcuseae the huamn mnid deos not
 raed ervey lteter by istlef, but the wrod as a
 wlohe. Amzanig huh? yaeh and I awlyas
 thuoght spleling was ipmorantt!

Figure 4

Robustness

is the capacity of a system to respond to noises or alterations. The translation from analogical to digital model implies an increase of the fragility of the model. This image demonstrates how the human is capable of adapting to distortions of a message. This same condition is very difficult to obtain with a computer model. Image by courtesy of Y. Wang, presented at the Conference on Language as a Complex Adaptive Systems Santa Fe Institute, Beijing, in July 2005.

The methodological challenge is to develop a pilot model supporting the designer in the mediation between complex physical, social, economic and structural constraints and a formal response. The research questions the concepts of resemblance, repeatability, robustness and efficiency of the solution developed.

ARD is an adaptable device to unfold a set of formal solutions answering specific performance requirements. In every case study of the ARD research, the researchers enunciate the reasons why they are using a specific device to analyse (as in the case of ARD1 *Copertura*), to demonstrate or to explore (as in the case of ARD3 *Formal Modulation for Light Performance in a Women's Hospital*). ARD's first task is to obtain a deeper understanding of the way in which architectural information is processed, represented and organised, and then transformed into an abstract model. The method contained in this proposal investigates the existing relationships between the perception of a specific reality and its translation into a set of elements that can be manipulated through computerised models by engaging with the idea of resemblance and robustness.

The ARD research is supported by the study and collection of examples illustrating the logical connectionism that operates in the articulation of architectural projects through the definition of a set of associative and dynamic relationships.²¹

ARD research operates on two planes. On the theoretical level it is based on the selection of basic examples in which the architectural project can be expressed as a theoretical construct. Representing physical, structural or social processes, with a set of variables and a set of logical and quantitative relationships, ARD uses Holland's ideas of adaptation (Holland, 1992, 1995, 1997) for the typological evolution of the built environment in terms of adaptation to the external (site) conditions.

In order to achieve the logical model ARD, NSU researcher subdivides the process, into a system of elementary units: attributes and building blocks. Physical and conceptual problems are fragmented into attributes and building blocks. From a methodological point of view, in order to 'reduce' a specific reality into a set of elementary units, ARD refers to the experiences developed in other scientific fields.

This task requires the analysis of the conditions in which architectural needs and performances can be represented through sets of measurable units: attributes and building blocks. The presence or absence of a specific attribute would produce as output the appropriate behaviour (transformation of the physicality of the space, transformation of the process that affects the physicality.)

Expression of architectural principles is through a set of dynamical relations: articulation of the project in a set of relations and translation of the project input in an abstract symbolic language. The expression of architectural concepts through a set of dynamical relations can be synthesised in the following tasks: translation of architectural formal, functional and technological principles into a set of constraints; expression of the constraints identified in the previous phase in set dynamical relations, potentially through the employment of Agent-Based Models, Adaptive Models and Weighted Features (Livi, 2004).

ARD research is also based on the development of specific case studies in collaboration with other academic institutions and national architecture firms with the goal of consolidating and refining the tools and methodologies detected in the theoretical research. Such an operation allows testing and verifying the resemblance and robustness of the ARD architectural model. The case studies have the goal of trimming and calibrating the ARD tool. They are also useful for analysing which tool is able to supply concrete answers and which of them can be operated with a satisfactory level of reliability.

The goal is to provide a set of key factors that lead to the formulation of indicators that enable the monitoring of relationships operating in the definition of the formal design, functional and engineering problems.

From an epistemological point of view ARD challenges the boundary between the measurable and the non-measurable architectural dimensions.

Notes

- 1 Caterina Tiazzoldi. Adjunct Professor at the Graduate School of Architecture, Planning and Preservation at Columbia University, post doc researcher at the DIPRADI, Politecnico di Torino, Presented a PhD thesis on the topic of architecture and nonlinear strategies. She is the co-founder and co-director of the research lab Nonlinear Solutions Unit at the GSAPP, Columbia University NY, and teaches in various academies in the USA and Europe. Her work constantly challenges the boundary between the *Measurable* and the *Non-measurable* dimensions of architecture.
- 2 Caterina Tiazzoldi, *Automatismi o Strumenti Non Lineari di Progettazione*, PhD thesis, Politecnico di Torino ,May 2006.
- 3 John Holland (2 February 1929) is an American scientist and Professor of Psychology and Professor of Electrical Engineering and Computer Science at the University of Michigan, Ann Arbor. He is a pioneer in complex system and nonlinear science. He is known as the father of genetic algorithms.
- 4 Cosma Shalizi, External Professor, Santa Fe Institute, Assistant Professor, Carnegie Mellon University, Statistics Department. Cosma Shalizi works on methods for building predictive models from data generated by stochastic processes, and applying those models to questions about neural information processing, self-organisation in cellular automata, and so forth. All of this is about using tools from probability, statistics and machine-learning to understand large, complex, nonlinear dynamical systems.
- 5 Eisenman P. *Diagram Diaries*, Thames & Hudson, London, 1999, p 27.
- 6 A classical example of this type of use of a model is when a medical doctor recognises a disease from the presence or absence of a chemical component in the blood: the interpretation of the 'blood components model ' allows him/her to demonstrate a hypothesis concerning the status of the patient.
- 7 Holland, J. *Complex Adaptive Systems*, lecture at the, CSSS 2005, Complex Summer School Systems, Beijing, 2005
- 8 '[...] It is a way of triggering the diagram as a trigger for their design process. The design process involves human beings and involves back and forward and going up where you have not been before.' Peter Eisenman: *Automatism in architecture*; interviewed by Caterina Tiazzoldi in July 2004.
- 9 Gilles Deleuze , (January 18, 1925 – November 4, 1995) was a French philosopher of the late 20th century. From the early 1960s until his death, Deleuze wrote many influential works on philosophy, literature, film, and fine art. His most popular books were the two volumes of *Capitalism and Schizophrenia*: *Anti-Oedipus* (1972) and *A Thousand Plateaus* (1980), both co-written with Félix Guattari. His books *Difference and Repetition* (1968) and *The Logic of Sense* (1969) led Michel Foucault to declare that "one day, perhaps, this century will be called Deleuzian."
- 10 'But unlike traditional forms of representation, the diagram as a generator is a Mediation between a palpable object, a real building, and what can be called Architecture's interiority' (Peter Eisenman, *Diagram Diaries*, Universe Publishing, 1999, P.35).
- 11 Peter Eisenman: *Automatism in architecture*; interviewed by Caterina Tiazzoldi in July 2004.
- 12 'So much for the praises of a moderate reductionism, alive to the importance of interactions. How do we actually set about reducing phenomena and explaining emergence? By constructing a model. What is a model? We can use one thing (say, a globe) as a model of another (say, the surface of the Earth) if we can find a way of translating, or, as the mathematicians say, mapping, from one to the other which doesn't mess up the relations we're interested in. Then anything we learn about the model can be translated into a discovery about the modeled. (Holland includes things like the Game of Life among models, even though they do not fit this definition. Perhaps, like his board-games, they are to be regarded as models of imaginary worlds.) Models are only good if they're easier to handle and learn about than what they model, and if they really do accurately map the relations we're interested in. How does one find such a model?' Here Holland leaves us hanging, from the end of chapter two, on models, to the last chapters of the book. Despite having co-authored a whole (good) book on induction, his answer to the 'How?' question is 'Nobody knows.' He offers some sage advice --- become intimately familiar with the problem (no 'I could look that up'), learn the related problems and the tricks and the oral tradition which go

with them, be on the lookout for analogies and exploit them.

<http://www.cscs.umich.edu/~crshalizi/reviews/holland-on-emergence/>.

- 13 Ludwig Eduard Boltzmann (February 20, 1844 – September 5, 1906) was an Austrian physicist famous for his founding contributions in the fields of statistical mechanics and statistical thermodynamics. He was one of the most important advocates for atomic theory when that scientific model was still highly controversial.
- 14 Jules Henri Poincaré (April 29, 1854 – July 17, 1912) French mathematician and theoretical physicist, and a philosopher of science. Poincaré is often described as a polymath, and in mathematics as The Last Universalist, since he excelled in all fields of the discipline as it existed during his lifetime.
As a mathematician and physicist, he made many original fundamental contributions to pure and applied mathematics, mathematical physics, and celestial mechanics. He was responsible for formulating the Poincaré conjecture, one of the most famous problems in mathematics. In his research on the three-body problem, Poincaré became the first person to discover a chaotic deterministic system which laid the foundations of modern chaos theory. He is considered to be one of the founders of the field of topology.
Poincaré introduced the modern principle of relativity and was the first to present the Lorentz transformations in their modern symmetrical form. Poincaré discovered the remaining relativistic velocity transformations and recorded them in a letter to Lorentz in 1905. Thus he obtained perfect invariance of all of Maxwell's equations, the final step in the formulation of the theory of special relativity.
- 16 Combinatorial logic operating in the interior components of a system such as modules (building block) and attributes, in science as in architecture, provides innovative solutions. Image by courtesy of John Holland, from the lecture 'Genetic Algorithms and the Study of Complexity', Santa Fe Institute, Beijing, July 2005.
- 17 William Bateson (August 8, 1861 – February 8, 1926) was a British geneticist. He was the first person to use the term genetics to describe the study of heredity and biological inheritance, and the chief populariser of the ideas of Gregor Mendel following their rediscovery in 1900 by Hugo de Vries and Carl Correns.
- 18 Girvan M., Newman M.E.J., 'Community structure in social and biological networks', Proceedings of the National Academy of Sciences of the United States of America, 2002.
- 19 Automatism is a surrealist technique involving spontaneous writing, drawing or the like practised without conscious aesthetic or moral self-censorship. Automatism has taken on many forms: the automatic writing and drawing initially (and still to this day) practised by surrealists can be compared to similar, or perhaps parallel phenomena, such as the non-idiomatic improvisation of free jazz[1].
Surrealist automatism is different from mediumistic automatism, by which the term was inspired. Ghosts, spirits or the like are not suggested to be the source of surrealist automatic messages.
- 20 Automatism, being self-sufficient, is able to produce something far from the prefigured idea of the designer
- 21 For example, the work of architects such as John Frazer Frazer and Bernard Cache are focused on the expression of architectural problems through a set of associative relations bent on creating a direct connection between a specific reality and its representation (associativity).

